Laser Trapping Radioactive Atoms for Precise Weak Interaction Tests

M.A. Rowe, S.J. Freedman, B.K. Fujikawa, G. Gwinner, S.-Q. Shang, P.A. Vetter, E.G. Wasserman

Radioactive isotopes confined in neutral atom traps will play an important role in future precision measurements of weak interactions such as the parity violating asymmetry in the β-decay of spin-polarized nuclei, electron-neutrino correlations, and parity violation in atoms. Traps provide a localized, isotopically pure sample in which source scattering is eliminated, and neutral atoms are easily manipulated by optical pumping techniques to achieve high nuclear spin polarization.

Recent improvements to our apparatus have provided us with 50,000 trapped ^{21}Na atoms. In the past, our efforts have been directed towards increasing the size of the trapped sample from the first demonstration of the technique towards a useful level. Our advances during the last year have produced a ^{21}Na trap large enough to begin experiments with radioactive atoms. A precise determination of the ground state hyperfine splitting is now in progress. We will then begin a measurement of the β-asymmetry parameter in the mirror decay of $^{21}\mathrm{Na} \rightarrow {}^{21}\mathrm{Ne}$ to search for deviations from the V-A structure of the charged current weak interaction, e. g. from right handed currents.

^{21}Na ($t_{1/2}$ = 22 sec) is produced on-line at the 88" Cyclotron at LBNL with the ^{24}Mg (p, α)^{21}Na reaction. Efficient extraction of ^{21}Na from our MgO target is crucial for achieving large traps. During 1996, we installed a new, more reliable target oven. In target development runs with this oven we determined that sintering and slow diffusion in the MgO powder kept the yield low from a powder target. Now we use a series of thin, free-standing, pressed MgO disks. Another improvement has been better collimation of the ^{21}Na atomic beam into the laser trap region. Since the vapor pressure inside our target oven is much lower than standard atomic beam sources, we can use long narrow exit channels to focus the outgoing beam. We now use channels with a length-to-diameter ratio of 25:1. These refinements provide more ^{21}Na in the forward direction, yielding more trapped atoms.

We have made a preliminary measurement of the atomic ground state hyperfine splitting of ^{21}Na using our trapped atoms (Fig. 1). We induce transitions between the two ground state hyperfine levels with microwaves and then probe the atoms with a laser. A measurement of the atomic fluorescence tells us how many atoms make the transition as a function of microwave frequency. With an improved magnetic field configuration and a new microwave antenna, a final frequency measurement will be made with a precision of 1 part in 10^7. We have already achieved this accuracy with the stable isotope, ^{23}Na. This microwave work can also be applied to characterize the nuclear polarization of our trapped atoms, which will be necessary to extract weak interaction parameters from our measurements on the β-decay. In our last run of 1996 at the 88" Cyclotron, we observed β decays of our trapped sample with an in-vacuum detector. This data provides us with signal and noise levels which will guide design changes for the β asymmetry measurement.

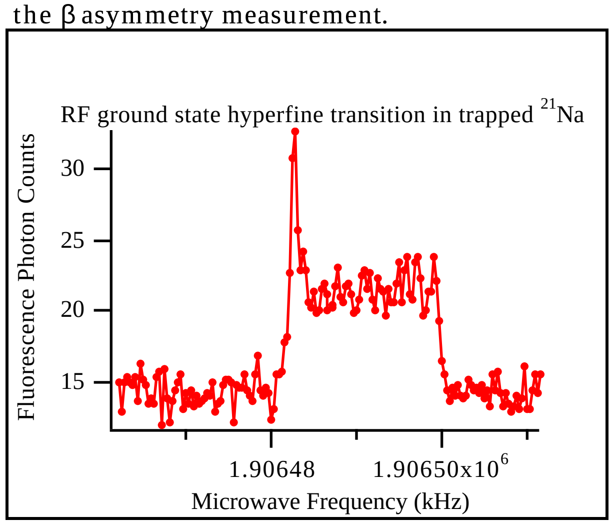

Fig. 1.Microwave absorption by trapped ^{21}Na.